Chart #1

Ionospheric Mappers

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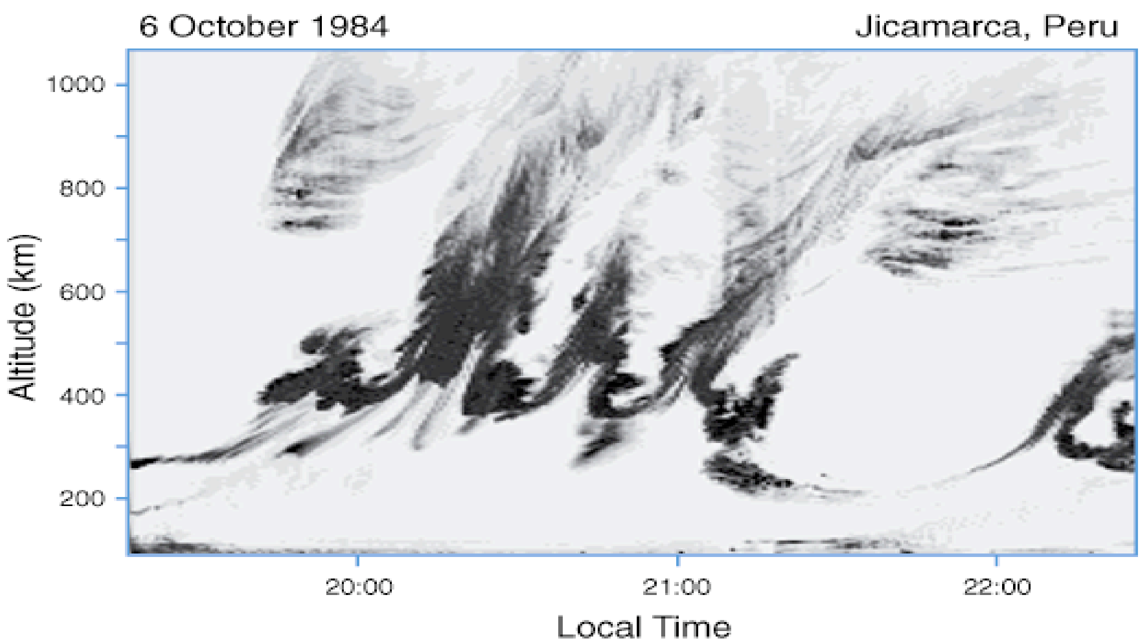
Ionospheric Mappers



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Living With a Star
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Ionospheric Mappers

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Primary LWS Task:

To carry out a program of scientific observations and research that will enable improved space weather specification models, nowcasting, and forecasting.

Ionospheric Mappers -- Region of Focus:

The Earth's Ionosphere -- Upper Atmosphere
(100-2000 km)

- The ionosphere is a highly dynamic environment that undergoes significant spatial and temporal variations with latitude, local time, and season.
- It is directly coupled to the magnetosphere and is the primary sink for solar wind and magnetospheric energy and momentum deposition in the Sun-Earth connections chain.
- The Earth's Ionosphere/Upper atmosphere includes numerous Space Weather applications

Ionospheric Mappers -- Integrated Science and Space Weather Goals:

1. Global characterization and understanding of the ionosphere/upper atmosphere
2. Improved accuracy of ionospheric specification models.
3. Improve forecast and "nowcast" accuracy.

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Space Weather Effects, or
Beyond our desire to understand Nature, why do we care about the ionosphere?

Human presence in space (e.g., Shuttle, Space Station)

→ Affected by solar and magnetic radiation sources including impulsive events.

→ Space station, EVA astronauts and free-flying "portable" satellites may undergo differential changing.

Communications

→ HF and other frequencies disrupted by scintillations created by irregularities, Maximum Useable Frequency determined by plasma density along path.

→ Affects HF ground communications as well as satellite communications.

Navigation (GPS and LORAN)

→ GPS positional errors are function of ionospheric density irregularities, scintillations.

Satellite Systems

→ Highly susceptible to radiation, charging, if not designed properly.

Orbital Drag -- collision avoidance, re-entry, orbital debris

→ Low earth orbit satellites may re-enter due to increased drag including "abrupt" variations.

Currents in Space

→ Induced currents in long, ground-based conductors may disrupt power grids.

Chart #4

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Understanding Physical Properties (Science)

Understanding Physical Processes (Science)

Overarching goal: Obtain in-depth understanding of ionospheric/thermospheric physical processes needed to enable Space Weather forecasts.

- **Energetic Particles.** Understand global temporal and spatial distributions of energetic particle precipitation and relate to magnetosphere, solar wind.
- **Plasma Irregularities.** Discover the sources, dynamics, and evolution of plasma instabilities in the ionosphere that create HF and GPS scintillations.
- **Plasma Structure.** Understand how geomagnetic storms drive thermospheric plasma density behavior, including at mid- and low-latitudes (i.e., the disturbance dynamo).
- **Neutral Density Variations.** Determine how solar dynamics and magnetospheric forces create neutral density variations and cellular structure and how they evolve.
- **Currents.** Fully understand the creation of ionospheric currents including field-aligned current closure.
- **Physical Models.** Fully specify and understand ionospheric and thermospheric properties to enable predictive capability.

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Establish Space Weather Parameters -- Operation

Establishing Space Weather Parameters (Operations)

Overarching Goal: Gather simultaneous global observations at all latitudes, longitudes to assess ionospheric space weather conditions for space weather applications, to facilitate nowcasting.

- **Energetic Particles.** Fully specify the space radiation environment to increase astronaut safety, spacecraft reliability and satellite systems.
- **Plasma Irregularities.** Gather spectral, spatial, and temporal irregularity distributions over scale lengths of 100's of km to 10's of cm and provide nowcasting for communication and navigational RF systems.
- **Plasma Structure.** Fully characterize the ionospheric plasma density at all altitudes (100-2000 km), latitudes, longitudes, local times, and seasons and understand its effect on communications and irregularity generation.
- **Neutral Density Variations.** Fully characterize the thermospheric neutral density at all altitudes (100-1000km), latitudes, longitudes, local time, and seasons, including spatial scales from 100's of km to <1 km and understand its effect on satellite orbits and debris drag.
- **Currents.** Characterize the global ionospheric currents and their relation to plasma density variations and magnetospheric drivers.
- **"Maps".** Produce ionospheric "maps"of density and irregularities updated every hour.

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Ionosphere Mappers -- "Strawman" Mission Approach

GOALS: 1) Obtain snapshots of ionospheric Space Weather conditions on a global scale.

2) Obtain physical parameters needed to predict space weather conditions.

Problem: Average conditions from a single satellite over a long time span smooth out variations, mask abrupt, large-scale spatial, temporal changes.

Approach: Gather global data of key Space Weather Ionospheric Parameters and Physical Parameters using multiple platforms.

→ Create time-space dependent maps of the ionosphere at 450 km including neutral density and drag effects, plasma density, irregularities, impulsive radiation input, GPS and HF scintillations, currents, winds, and plasma drifts.

→ Develop physical models to predict Space Weather Parameters

Theory/Modelling: Determine measurement set needed; Number of spacecraft and inclinations needed.

Open question: Provide real-time monitoring at this time?

Chart #7

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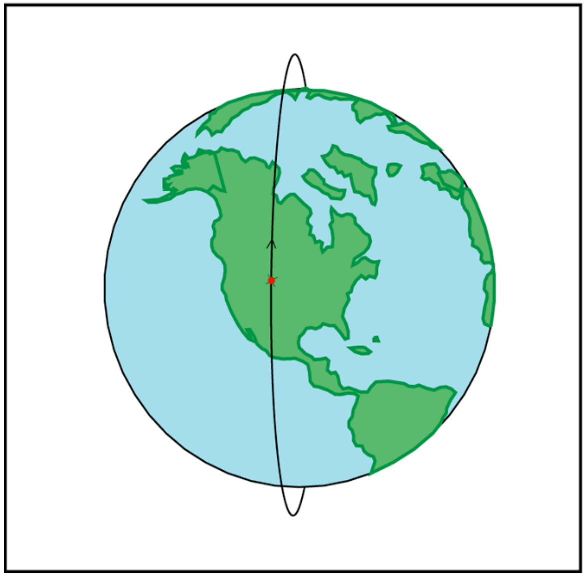
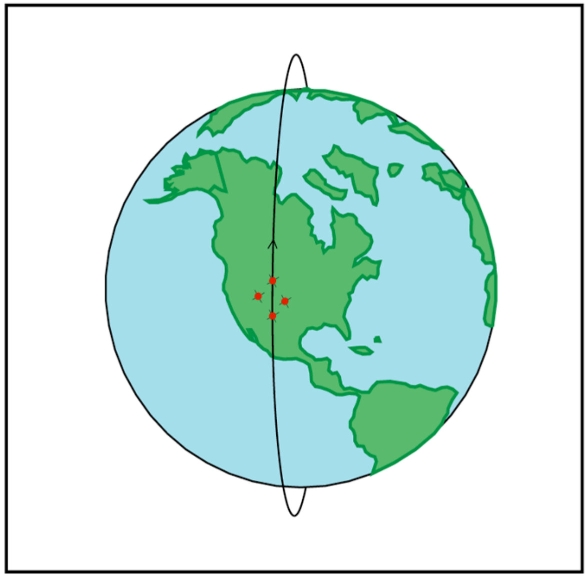
Observational Platform "Evolution"

Single Satellite



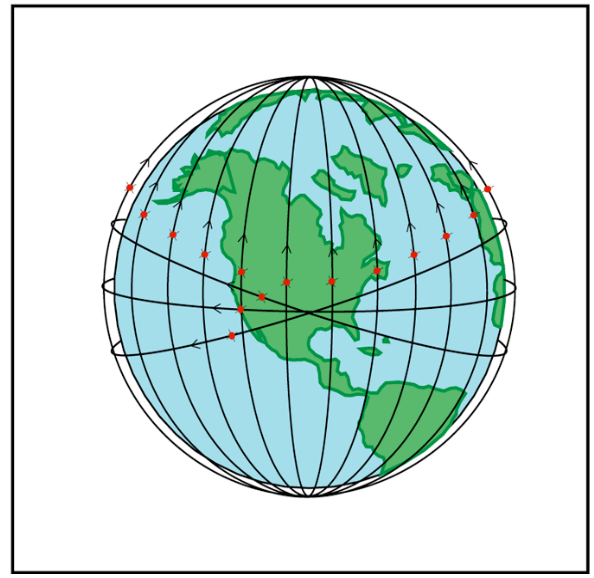
- Event Studies, Exploration
- Provide Average Global Conditions
- Example: **Dynamics Explorer-2**

Cluster of Satellites



- Event Studies that separate Space and Time
- Provide refined Average Global Conditions
- Example: **Global Electrodynamics Connections**

Global "Network" of Satellites



- Global coverage with simultaneous observations at all latitudes, local times
- Uncovers global-scale processes, coupling to other regions; provides event studies in "big picture"
- Enable tomography and other RF experiments (e.g., GPS occultations)
- Example: **Ionospheric Mappers**

Chart #8

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Space Weather "Strawman" Measurement Requirements

Space Weather Application	Measurement	Candidate Instruments
Space Radiation Effects	Energetic Particles	High Energy Particle Detector
HF Propagation Effects, Spacecraft Charging	Plasma Density	Langmuir Probe, Sounder, Plasma Frequency Probe, Tomography
Broadband Scintillations	Plasma Irregularities (ELF-HF)	E-Field, ΔN/N Wave Detectors
GPS Scintillations	GPS Phase, Tomography	GPS Receiver, Tomography
Drag Effects	Neutral Density	Accelerometer, Ionization Gauge, Orbit Analysis
Current Induction	Magnetic Field Variations	Magnetometer

Science Topic*	Measurement	Candidate Instruments
Neutral Winds, Instability Drivers	Winds	Mass Spectrometer with Baffles; Hanson Anemometer; RPA for ram winds
Plasma Movement, Instability drivers	Plasma drifts	Ion Velocity Meter; E-Field Probes

* Needed for predictive capability and understanding of physical processes.

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"Summary" of Strawman, "First Cut" Mission

Description: Global Array of identical ionospheric Space Weather monitors.

Instruments: Complement of plasma, neutral, energetic particle, and RF propagation experiments controlled by a single flight computer.

Spacecraft and Orbit: A total of N (N = 10 or more) satellites in circular orbits at 450 km spaced at a variety of inclinations; include small propulsion system for station keeping.

Mission Life: 3-5 years for full constellation.

Space Access: Either individual launches (e.g., on Pegasus-class vehicles) or multiple satellites launched on a series of medium class ELVs with dog legs.

Launch Date: 2008

Summary: Ionospheric Mappers will provide a major leap forward in our knowledge of the Earth's Upper Atmosphere.

Next Steps: Requirements, Study, Optimization, and Implementation.